NASA/CR- 97- 205776

Final Report for NASA Grant NAG 5 2866

NASA grant NAG 5 2866, funded by the Astrophysics Theory Program, enabled the study the Kelvin-Helmholtz instability in protostellar jets. In collaboration with co-investigator Philip Hardee, the PI derived the analytic dispersion relation for the instability in including a cooling term in the energy equation which was modeled as one of two different power laws. Numerical solutions to this dispersion relation over a wide range of perturbation frequencies, and for a variety of parameter values characterizing the jet (such as Mach number, and density ratio) were found. It was found that the growth rates and wavelengths associated with unstable roots of the dispersion relation in cooling jets are significantly different than those associated with adiabatic jets, which have been studied previously. In collaboration with graduate student Jianjun Xu (funded as a research associate under this grant), hydrodynamical simulations were used to follow the growth of the instability into the nonlinear regime. It was found that asymmetric surface waves lead to large amplitude, sinusoidal distortions of the jet, and ultimately to disruption. Asymmetric body waves, on the other hand, result in the formation of shocks in the jet beam in the nonlinear regime. In cooling jets, these shocks lead to the formation of dense knots and filaments of gas within the jet. For sufficiently high perturbation frequencies, however, the jet cannot respond and it remains symmetric. Applying these results to observed systems, such as the Herbig-Haro jets HH34, HH111 and HH47 which have been observed with the Hubble Space Telescope, we predicted that some of the asymmetric structures observed in these systems could be attributed to the K-H modes, but that perturbations on timescales associated with the inner disk (about 1 year) would be too rapid to cause disruption. Moreover, it was discovered that weak shock "spurs" in the ambient gas produced by ripples in the jet surface due to nonlinear modes of surface and/or body waves could accelerate the ambient gas to low velocity. This latter effect represents a new mechanism by which supersonic jets can accelerate low velocity outflows.

Two refereed publications in the Ap.J. acknowledged this grant:

1. "The Stability of Cooling Jets: I. Linear Analysis", by P. Hardee & J.M. Stone, *The Astrophysical Journal*, in press (1997).

2. "The Stability of Cooling Jets: II. Nonlinear Simulations", by J.M. Stone, J. Xu, & P. Hardee, *The Astrophysical Journal*, in press (1997).

Funds from this grant supported Jianjun Xu as a research associate, summer salary for the PI and co-I, and paid travel and publication costs associated with this research.